

Production cost and competitiveness in major salmon farming countries 2003–2018



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ABSTRACT

This paper investigates the development of production costs in aquaculture of Atlantic salmon between the five main producer countries. A unique data set allows us to analyse the development in the period 2003 to 2018. Costs have developed differently between countries, with Chile and the Faroe Islands standing out with strong and different changes. Chile sees a strong increase in cost and moves from being the lowest to the highest cost producer, and then to lowest again. The Faroe Islands has the opposite development and moves from being the highest to one of the lowest cost producers. For Norway and Canada the changes are considerably smaller, while Scotland has had the most marked cost increase. For the Faroe Islands and Chile, major disease outbreaks play a major role in explaining the change in cost. Differences between countries are also related to scale, natural conditions, currency development and regulations. Results show that Norway's position as the leading salmon producing country in terms of market share seems justified by its low production cost.

1. Introduction

Productivity growth leading to reduced production cost and increased competitiveness is a key factor in the success of modern aquaculture (Asche, 2008; Kumar and Engle, 2016). Less attention has been given to cost development in different countries for the same species. This is important as the cost level is the main indicator of the competitiveness of the industry in a specific country. Hence, one would expect production to be reallocated geographically if countries have different cost developments.

A main reason this issue has received limited attention is that cost data at firm and industry level are hard to come by, and data that are somewhat comparable between different countries are even less available. In this paper, we have access to a unique data set on production cost for Atlantic salmon in the five largest salmon producing countries for the period 2003–2018. The data enables us to compare the development in production cost in the five countries over time and to associate this with production growth. This is a particularly interesting period for salmon aquaculture, as there have been substantial changes in production shares between different countries, with disease

outbreaks and impacts of regulations as major explanations.¹

Atlantic salmon (*Salmo salar*), hereafter just salmon, is a particularly interesting species to study for several reasons.² It is one of the most successful aquaculture species, with a higher production growth than for aquaculture in general (Kobayashi et al., 2015). This is to a large extent due to the fact that salmon producers are in the forefront in a number of productivity enhancing categories such as production technology and supply chain development (Smith et al., 2010; Kumar and Engle, 2016; Asche et al., 2018c; Kumar et al., 2018). Salmon is also produced in relatively few countries, exposed to different economic shocks and with substantial geographical dispersion and considerable differences in biophysical conditions. Five countries made up 95.6% of the production in 2015. Norway is the largest with a production share of 55.3% and is together with Scotland (7.6%) and the Faroe Islands (3.3%) in Europe. The second largest producing country Chile, (25.4%), is in South America, and Canada (6%) in North America. The remaining 4.4% is spread among eight countries with severe limitations to their production capacity due to availability of appropriate sites. Hence, there are relatively few countries that can make up production shortfalls in other countries, and substantial production shortfalls in any

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¹ However, it is worthwhile to note that there is a well integrated global market so that the price development is similar in the main production countries (Asche et al., 2018a).

² Atlantic salmon is the most important farmed salmon species by quantity, although significant quantities are also farmed of coho and trout, and smaller quantities of other species. In 2015, 86% of the production of farmed salmon was Atlantic (FAO Fishstat).

country can have a significant market impact.

There have been several shocks to the market that likely influenced the producer countries differently. The most important is a serious disease outbreak in Chile that climaxed in 2010. Chilean production was reduced by two thirds to 129 thousand tonnes in 2008 (Fischer et al., 2017; Quezada and Dresdner, 2017; Dresdner et al., 2019). This led to similar price increase in all markets, demonstrating that there is a well-integrated global market for salmon (Asche et al., 2018a). Hence, while the disease issues were highly problematic for Chile, it was largely beneficial for producers in the other countries through increased prices (Asche et al., 2018a). In addition, there are substantial concerns with respect to environmental impacts in all five major salmon producing countries that limit access to new production sites and increases in license capacity. With increased demand as shown in Brækkan et al. (2018), this further contributes to higher prices.

Consistent data series showing cost development over time is very hard to come by for any aquaculture species. The only exception is the production cost for Norwegian salmon, which is published annually based on a survey conducted by the regulator, the Directorate of Fisheries. There exist a number of productivity and cost function studies based on this data set starting with Salvanes (1989), and with Rocha Aponte and Tveteras (2019) and Roll (2019) as recent examples.³ These studies show how production cost declined rapidly until 2006, after which it has increased steadily.

Feed is the most important input factor in salmon aquaculture with a cost share of over 50% (Guttormsen, 2002; Asche and Oglend, 2016). Prices for the most important ingredients, fish meal and fish oil, are highly volatile and influenced by *El Ninos* (Oglend, 2013; Ubilava, 2014). Longer trends like climate change (Lorentzen, 2008; Hermansen and Heen, 2012) and regulatory system (Abate et al., 2018; Osmundsen et al., 2017; Nadarajah and Flaaten, 2017; Murray and Munro, 2018) have also been shown to influence production costs. With the geographical dispersion of the salmon producing countries, these trends are likely to have different impacts across countries. The prevention and treatment of sea lice has become a major cost component (Abolofia et al., 2017), likely to influence various countries differently. Disease prevalence and impacts often have major cost implications, and the different producer countries have faced different challenges in this area in the period under study.

The only study we are aware of that compares developments in productivity growth for different countries is Asche et al. (2003), placing salmon aquaculture within the general framework of Siggel and Cockburn (1995).⁴ They discuss how market shares reflect differences in productivity development corrected for regulatory impacts and show the development for the four largest salmon producing countries. However, as they acknowledge, market shares are only a proxy for production cost, as the causality normally goes from production cost to market shares. Currency changes may also have an impact on competitiveness between the five countries but will not be considered here. We have chosen USD as a reference as this is the trading currency for both American and Far-East markets, and the main invoice currency in international trade (Straume, 2014), and the main cost ingredients (feed ingredients) comes from USD denominated markets (Asche and Oglend, 2016).⁵ However, any strengthening (weakening) of a local

³ There exist productivity studies for a number of other species. However, these are all based on cross-sectional survey data that allow the researchers to derive insights about differences between firms, but not about cost development over time. Ali et al. (2018) and Mitra et al. (2019) provide some recent examples.

⁴ Bjørndal and Aarland (1999) provided a comparison of production cost in Norway and Chile, without being able to say anything about the development over time.

⁵ It should be noted that most of the salmon from Norway, UK and the Faroe Islands is sold in Euro. Straume (2014) provides an overview of the exchange rates used by Norwegian salmon exporters.

currency against the USD will then reduce (improve) competitiveness.

The paper is organized as follows: The production of salmon is presented first, with focus on historical development among producer countries. Next, production costs in the same countries are discussed, focusing on explanatory factors.

2. Salmon production

The produced quantity of salmon in the five countries investigated here, which makes up over 98% of total production, is shown by country in Fig. 1 for the period 1990–2018. Salmon farming is a relatively young industry, characterized by rapidly increasing production, from 230 thousand metric tons (mt) in 1990 to 2.2 million mt in 2018. It is noteworthy that all the countries show a strong growth in production, although with variations in the growth rate through the period under study (2003–2018). This is not surprising given the rapid production growth for the industry. The impact of the disease challenges in Chile is clearly visible around 2010, although it is worthwhile to note that by 2012 total production is back on the long run trend. Norway has been the main producing country throughout the period. This is even clearer in Fig. 2, where the production shares are shown. Norway's production share of 65.7% in 1990 is the highest measured in the data set, while the lowest Norwegian production share (41.7%) was recorded in 2001. Since 2001 Norway's production share has been increasing gradually, except for a strong short-term gain and loss during and after the disease crises in Chile. Chile's production share increased rapidly in the 1990s but has been stable with considerable variation around the mean in the 2000s. The UK's production share is the only showing a consistent decline, although also Canada's has declined in the 2000s.

Data availability has been relatively good in Norway, and Asche (1997) reported the first relationship between price, production cost and quantity produced. In real terms, the production cost in 2016 was about a third of what it was in 1985, as was the price. This is the relationship one would expect in a growing, competitive industry.

A number of productivity studies have been conducted on Norwegian data, with Vassdal and Holst (2011), Nilsen, 2010, Asche et al. (2013a), Asche and Roll (2013), Rocha Aponte and Tveteras (2019) and Roll (2013, 2019) as some recent examples.⁶ The main long-term results from these studies can be summed up as substantial technological non-neutral technical progress that is slowing down, leading to an increasing cost share of feed. However, recent data indicate that during the last ten years, this trend has been broken. Feed cost are rising, primarily due to increasing feed prices, but other costs are rising more, due to biological issues related to parasites and diseases (Iversen et al., 2019, Rocha Aponte and Tveteras, 2019). While one can still observe significant investment in technology, leading to technological progress, this progress is overshadowed by biological problems related to lice and disease as well as increased costs associated with higher capacity utilization due to the high prices. The technical change also increases the efficient scale (Asche et al., 2013b), and there still appears to be unexploited scale economies in most countries. Even though production technology is similar, there are considerable differences in site-level scale and physical conditions, regulations, capital intensity and other cost drivers (Iversen et al., 2019).

3. Methods and data

Salmon farming companies generally report production costs in annual or quarterly reports to the public and authorities, but they generally do not report production costs per kilo, as most companies consider this sensitive information. Costs are also aggregated in broad

⁶ Sandvold and Tveterås (2014) and Sandvold (2016) show that there has also been significant productivity growth in the production of smolt.

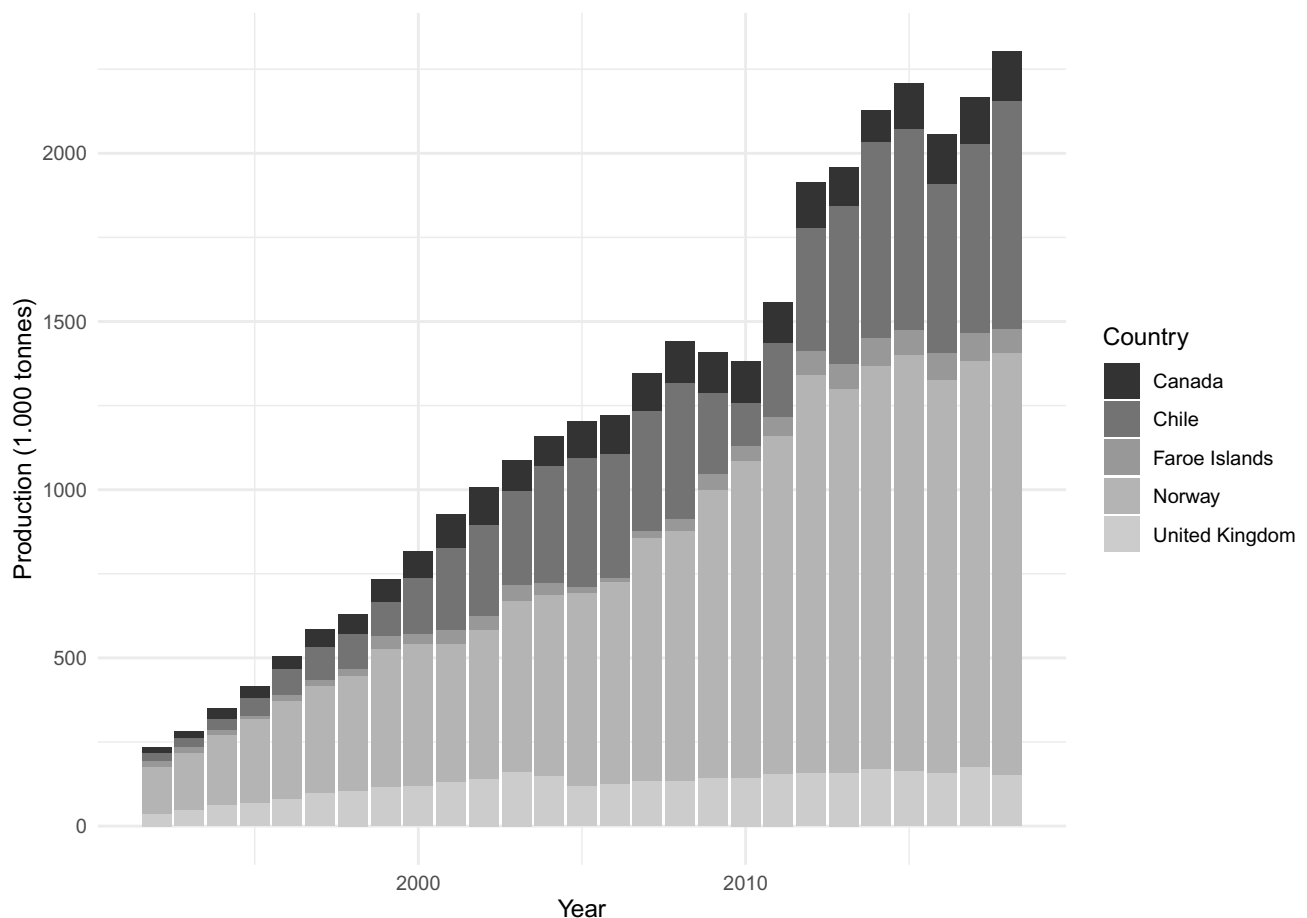


Fig. 1. Atlantic salmon production in the five largest producer countries. (Source: Kontali Analyse AS).

cost categories, and with varying levels of vertical integration among producers, costs associated with on-growing in sea-cages are often hard to isolate. Cost reporting practices from production also varies between companies, further complicating this approach. Cost comparisons thus require comprehensive gathering of primary data. Norway is (at least partly) an exception to the above, in that salmon farmers are required to provide the authorities with relatively detailed annual accounting and production data, allowing for a comprehensive estimation of average production costs for Norwegian salmon producing companies, published in an annual publication by the Directorate of Fisheries (Directorate of Fisheries, 2018). Such detailed data are not available for other countries. We have therefore performed a three-stage model for estimating production costs in the selected countries. To ensure comparability, the same estimation is also performed for Norway.

The first stage is the estimation of production cost per kilo for each country. As listed companies report EBIT per kilo sold for all countries they operate in, and sales price statistics are available, an estimate for production cost per kilo may be calculated (knowing also the sales volume or market share for the listed companies, and using their average as an estimate for other companies in each country).

The second stage breaks down production cost to major cost components (cost of smolt, feed, labour, other operating costs, depreciation and slaughter). This requires building a cost estimate bottom-up, considering the actual use of input factors in production. The seafood statistics and analytics firm Kontali Analyse AS maintains a cost model to estimate production costs per kilo produced in each country to provide such data. Data on various cost drivers such as feed prices, feed sales, feed conversion ratios, harvest weights, smolt release, smolt weights, smolt yield, cleaner fish, use of pharmaceuticals etc. are gathered to estimate factor input, and are combined with data on

mortality to calculate actual yield from input factors. For Norway, the model is populated every year, whereas in the other countries where data is less publicly available, data have been collected every third year. The cost estimates are to be considered country averages, but keep in mind that there is huge variation around this means. Cost is highly affected by the incident of disease, lice algae blooms, predators etc., and as these are unevenly distributed, costs vary considerably.

The third stage implies several methods for validating the model, to make sure the bottom-up approach (stage 2) match the overall estimates (from Stage 1) and the data from The Norwegian Fisheries Directorate. There are certain weaknesses in data access and methods that we seek to remedy through this stage. First, all interview data fed into the model are to some degree uncertain, until confirmed by other interviews or by checking towards other sources. Second, for data that are not publicly reported, our sample might not be representative. Representativity is sought obtained through a thorough check of data towards known data on smolt production, feed use, mortality, sales etc., so that all production through the value chain is accounted for and understood. Resulting cost estimates are also triangulated against the relatively detailed public reports from firms listed at stock exchanges, considering their share of production. Some uncertainty will remain.

3.1. Data

For Stage 1, annual accounting data and production data for all salmon producing firms that do publicly report their data are collected. Several firms have activities in sectors other than salmon farming, requiring the accounting data to be adjusted to reflect only the salmon farming activity (i.e. pulling out income and costs representing other activity).

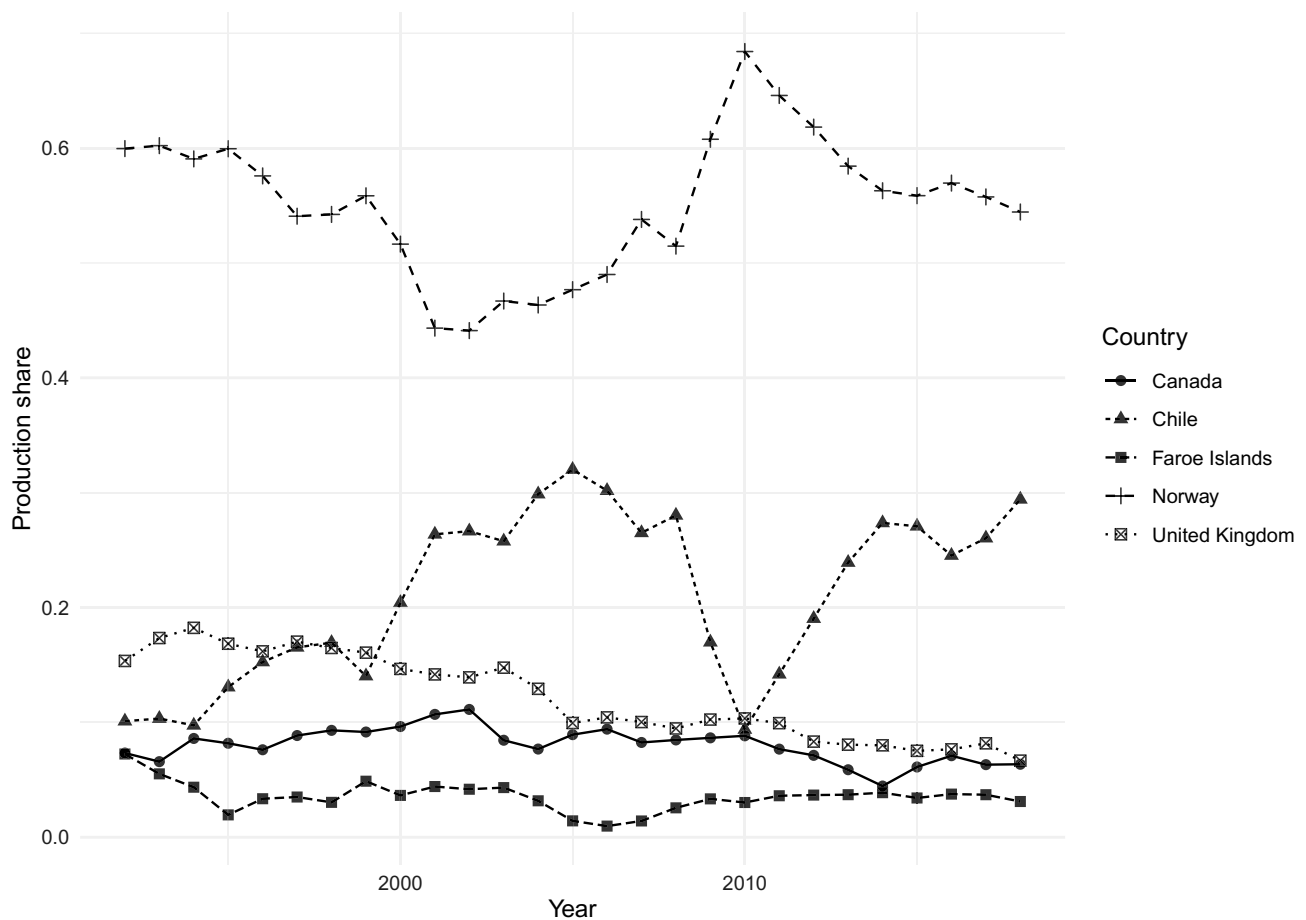


Fig. 2. Production shares of Atlantic salmon in five largest producer countries (Source: Kontali Analyse AS).

For Stage 2, information on smolt release, prices, feed use, mortality, harvest weight etc. are collected from different public sources, as well as from interviews, providing the basis for estimating smolt costs. This stage involves interviews with salmon farming companies, feed producers, producers of smolt, roe and fingerlings, salmon traders as well as independent experts. Such interview rounds are a costly and time-consuming affair, it has thus been performed on a third-year basis. Feed prices are estimated using both public and interview data and combined with information on biological performance such as mortality and feed conversion ratios. Other costs are estimated in a similar fashion, calculating total factor use, and dividing them by actual production. All public data and interview data are fed into a cost model that is run yearly for Norwegian producers, and every third year for other countries. Stage one could also be performed ex-post on a yearly basis, but for comparability we restrict reporting to every third year.

4. Results: production cost

For the analysis, US dollars (USD) are used as common currency to facilitate comparisons across countries.⁷ Real⁸ unit production cost is

⁷ It should be noted that salmon is sold in other currencies as well, notably most of sales to European countries are in Euro. Actual production decisions will be influenced by exchange rates in local currency as well. Tveteras and Asche (2008) show that due to highly efficient exchange rate markets, it does not matter which currency the price is denoted in for comparison purposes. Straume (2014) provide a detailed overview of currency use in Norwegian salmon exports.

⁸ All values are inflation adjusted to 2015-level using the annual consumer price index (CPI) from the US Bureau of Labor Statistics (www.bls.gov/cpi)

shown in Fig. 3 for every third year from 2003. Cost levels and development differs considerably between countries. None of the countries show a clear and stable trend in cost development, instead costs move both up and down between years.⁹ In Norway, Scotland and Canada costs are increasing 22, 28 and 18%, respectively, over the whole period, but with considerable changes in each three-year-period. Norway's costs are at a lower level than Canada and Scotland during the whole period. Scotland starts out with close to the highest costs, improves until 2009 and then increases again to have by far the highest cost. Canada starts out with slightly higher than average costs that continue to rise until 2012, when it is the highest cost producer. Towards 2015, Canada sees a major improvement in costs to lower than average, but this is mainly due to a favorable currency. In 2018 they return to a cost position above average.

The two countries that clearly stand out are Chile and the Faroe Islands, with generally opposite developments, and for both countries significant disease outbreaks are major factors in the cost development. Chile starts out as the lowest cost producer, then seeing rapid cost increase in both 2006 and 2009, with high cost until 2015 (the dip in 2012 is due to exchange rates), and then a significant decrease towards 2018, resuming the position as the lowest cost producer. The Faroe Islands for many years had a declining production cost, moving from the highest cost producer in 2003, to having the lowest production cost in 2012 and 2015, and then falling in line with Norway towards 2018. The main reason behind this anomalous development is that the Faroe

⁹ Bear in mind that measured in local currency, cost development shows a more consistent development, exchange rates contribute to some of this variation.

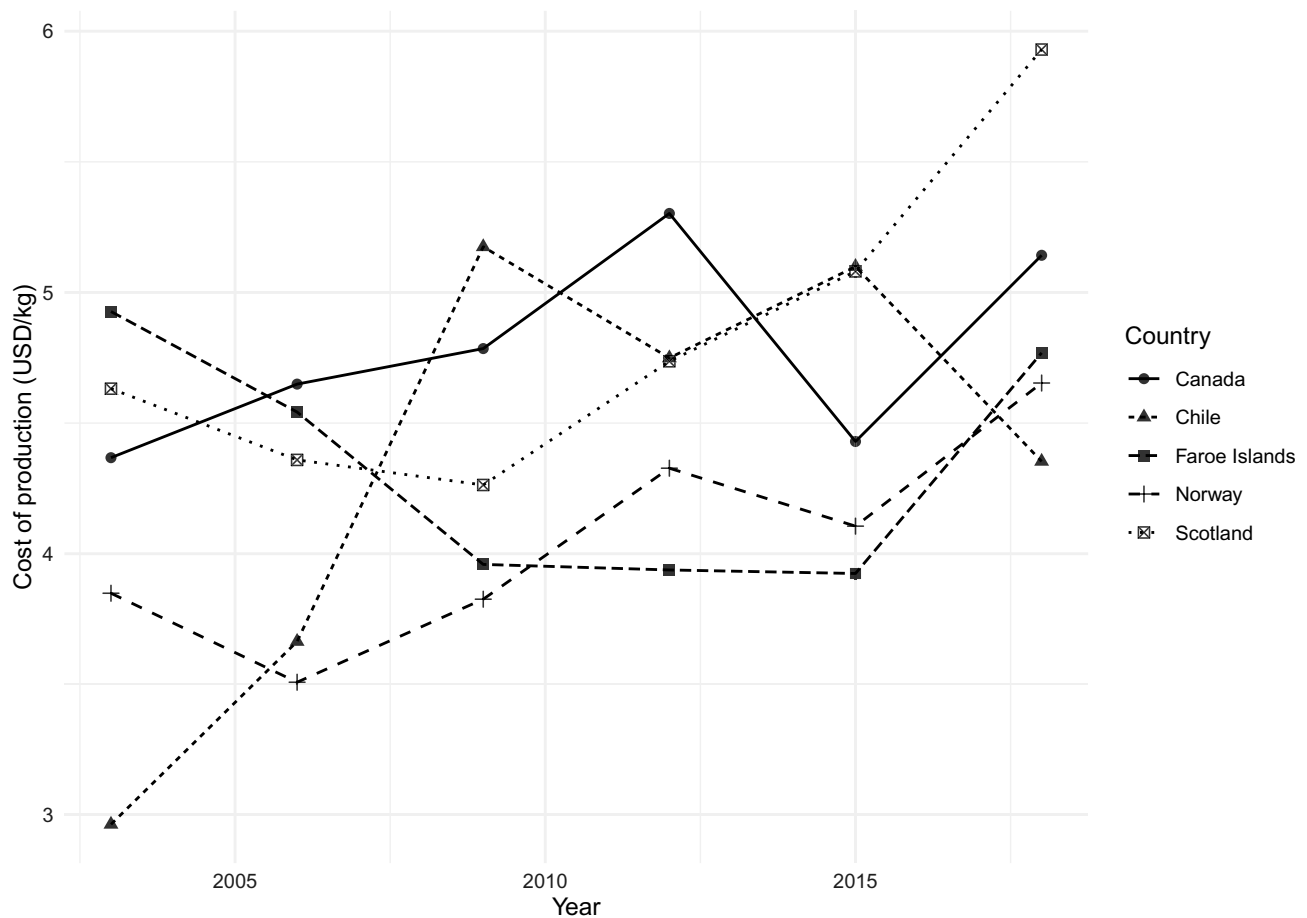


Fig. 3. Real production cost incl. Harvesting and packing costs, USD/kg gutted weight (2018-USD).

Island had a major ISA outbreak just after the turn of the century where production was more than halved and resulted in inflated costs. As such, Chile is far from being the only country where disease outbreaks have had major impacts on production. The main difference is that Chile's production was so high that the impact of the disease outbreak was felt globally. Throughout the period, Canada and the UK are high cost producers, and as such, their declining market shares may not be too surprising, although also regulatory barriers to expansion contribute to this.

Chile's production cost is significantly influenced by disease. The relatively strong increase from 2003 to 2006 gives additional evidence to the notion of stagnating production growth and serious disease issues well before the ISA was reported in 2007, as discussed e.g. by [Dresdner et al. \(2019\)](#). While 2009 does not quite coincide with the most dramatic disease year (2010), it is still clear that the disease issues made Chile go from having a clear cost advantage to becoming the highest cost producer for a period. Moreover, for various reasons, including an algae bloom in 2016 and costs associated with improving biosecurity and tighter regulations, Chile remained a higher cost producer after the disease outbreak. After the ISA outbreak was brought under control, and an improved cost position since 2015, Chile's production share has returned to previous levels.

Norway is among the two lowest cost producers throughout the

period. In 2003, Chile had significantly lower production cost, while Norway has the lowest production cost in 2006 and 2009, a period when its production share grows rapidly, and Chile and the Faroe Islands are going in and out of their respective ISA-crises. In 2012 and 2015 the Norwegian production cost is higher than the Faroe Islands, but still considerably lower than for the other three countries. Hence, with the limited capacity of the Faroe Islands, Norway's position as the leading salmon producing country over time seems justified by its low production cost. However, it is also clear that access to sites, site capacity and legal production constraints matter. In particular, one would expect the Faroe Islands' production share to increase if more sites were available. The Faroe Islands also face other constraints to their production, such as shallower depths on the sites and a limit to the number of smolts released per site. While nets in the Faroe Islands are 10–20 m deep, cages of the same size in Norway will typically have nets 40–50 m deep, each pen thus containing much more fish.

In [Fig. 4](#), the production cost per kilo is broken down by main cost categories in 2003 and 2018. The cost structure is relatively similar between the countries, with feed as the most important input factor. Feed accounts for a significant part of the cost increase in the period, with increases in feed cost ranging from 0,05 to 0,97 USD/kg. The only exception to this trend is The Faroes, where the reduction in disease issues have seen feed costs decreasing by 0,52 USD/kg. This indicates

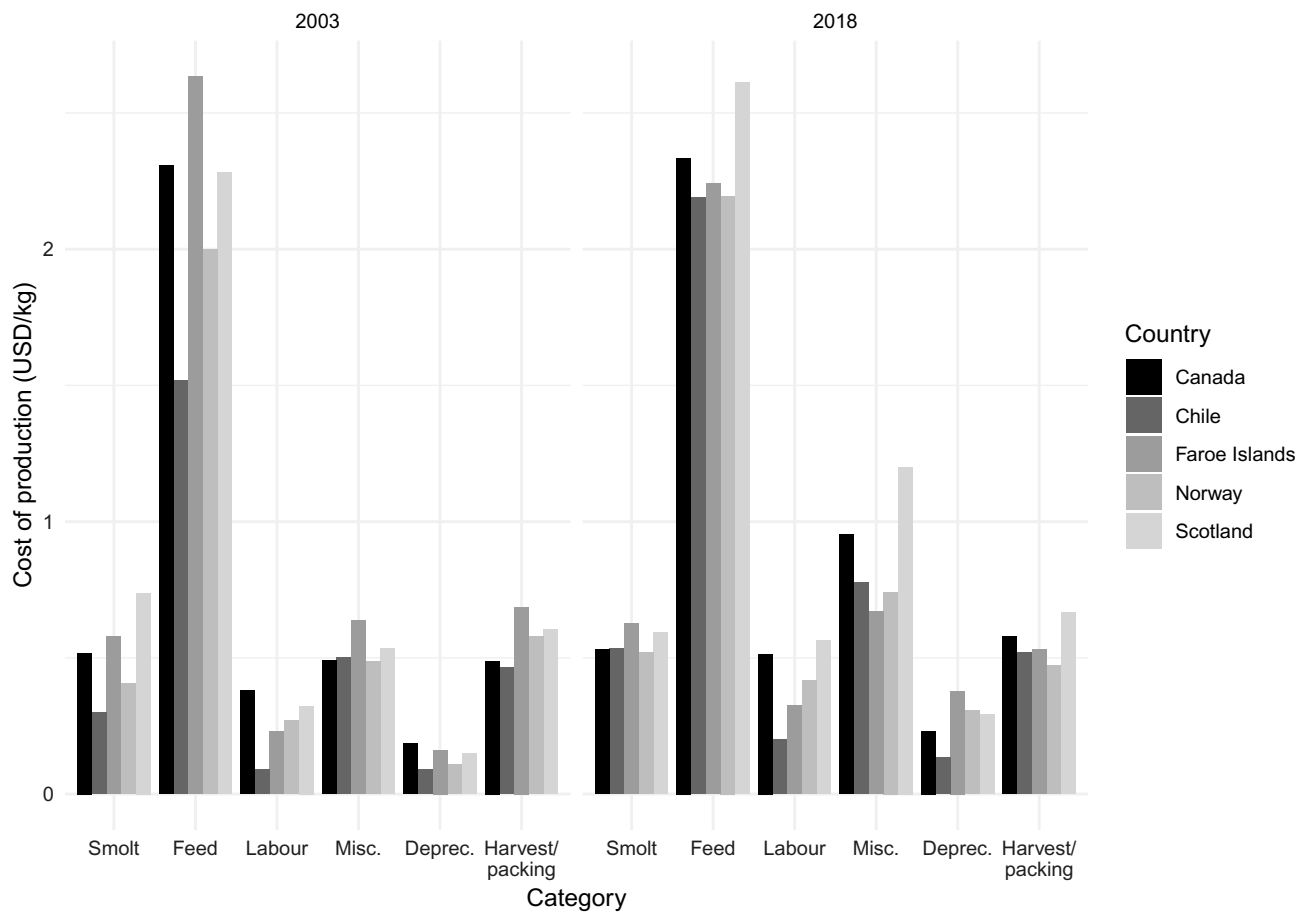


Fig. 4. Estimated unit production cost (per kg gutted weight) by main category in 2003 and 2018.

that the other factors have become more intensively used. Smolt costs are relatively stable, while labor and depreciation have increased somewhat. Miscellaneous costs, however, have increased strongly, both in absolute and relative terms. At least in Norway, this is primarily due to the lice treatment costs and a trend towards outsourcing of operational activities such as net pen cleaning and inspections as well as increasing overhead costs. In addition, it is worthwhile to note how Chile has gone from being a clear cost leader for smolt and feed to a cost more comparable to the rest. Chile still has the lowest labor cost and depreciation, leaving Chile with a cost advantage in 2018.

The smolt cost per kilo is determined by price per smolt, weight at harvest and losses. Smolt yield is the quantity of fish produced, measured in kilos, per released smolt. As shown in Fig. 5, smolt yield has generally been stable over time, with notable exceptions for Chile and the Faroe Islands. From 2004G¹⁰ and onwards, the Faroe Islands smolt yield improves significantly as they regain healthy production after an ISA crisis, and it surpasses all other producing nations primarily due to much stronger bio-sanitary measures. The industry consolidated into three players after the crisis. These split production zones between them, and coordinated release, harvest and fallowing, resulting in production with much improved biological results. For Chile, the smolt yield again gives a strong indication that the disease situation was highly problematic a long time before the ISA-outbreak was announced in 2007. It is also highly interesting to note how the smolt yield improves for the generations that are harvested after the worst disease outbreaks had resulted in a strong reduction of the biomass at sea. For Canada, Norway and the UK, the smolt yields are relatively stable, but

with a lower yield in the UK. This is at least partly due to higher water temperatures giving faster growth and higher turnover, shorter growth cycles and harvesting smaller fish.

Smolt cost may also be more important than indicated by the cost share, as the biological performance, particularly weight at harvest and losses in production, to a considerable degree depends on the quality of the smolt. Both weight at harvest and loss have strong implications for several of the other cost categories, and feed in particular. Hence, production losses are another important factor that influence production cost. Fig. 6 shows losses in terms of share of the released individuals that are not harvested and sent to the market.¹¹ There are several reasons for these losses, including smolts that do not survive the transfer to seawater, damages during handling, losses to predators, disease, escapes, lice treatment etc. Early loss is less costly than later when the fish has consumed feed and other cost items.

The main story is again that the Faroe Islands and Chile differ from the others, due to the previously described disease outbreaks. However, the Faroe Islands' response to the crises by instituting an improved governance system, among other adaptations, contributed to lowering the production losses. The main changes to the regulations were allowing only one generation per fjord, minimum distances between sites,

¹¹ Loss measured as number of individual fish corresponds with cost increases only if the size composition of the fish that is lost is constant. This is not always the case. We know that the size of lost fish is increasing in Norway, due to lice treatment leading to mortality of larger fish, and assume this might be the case in other countries as well, but we do not have sufficient information to estimate this effect. Most losses appear to be relatively small fish, but the economic loss is of course much larger when it is large fish that escape, get diseases etc.

¹⁰ Smolts released in 2004, G = Generation

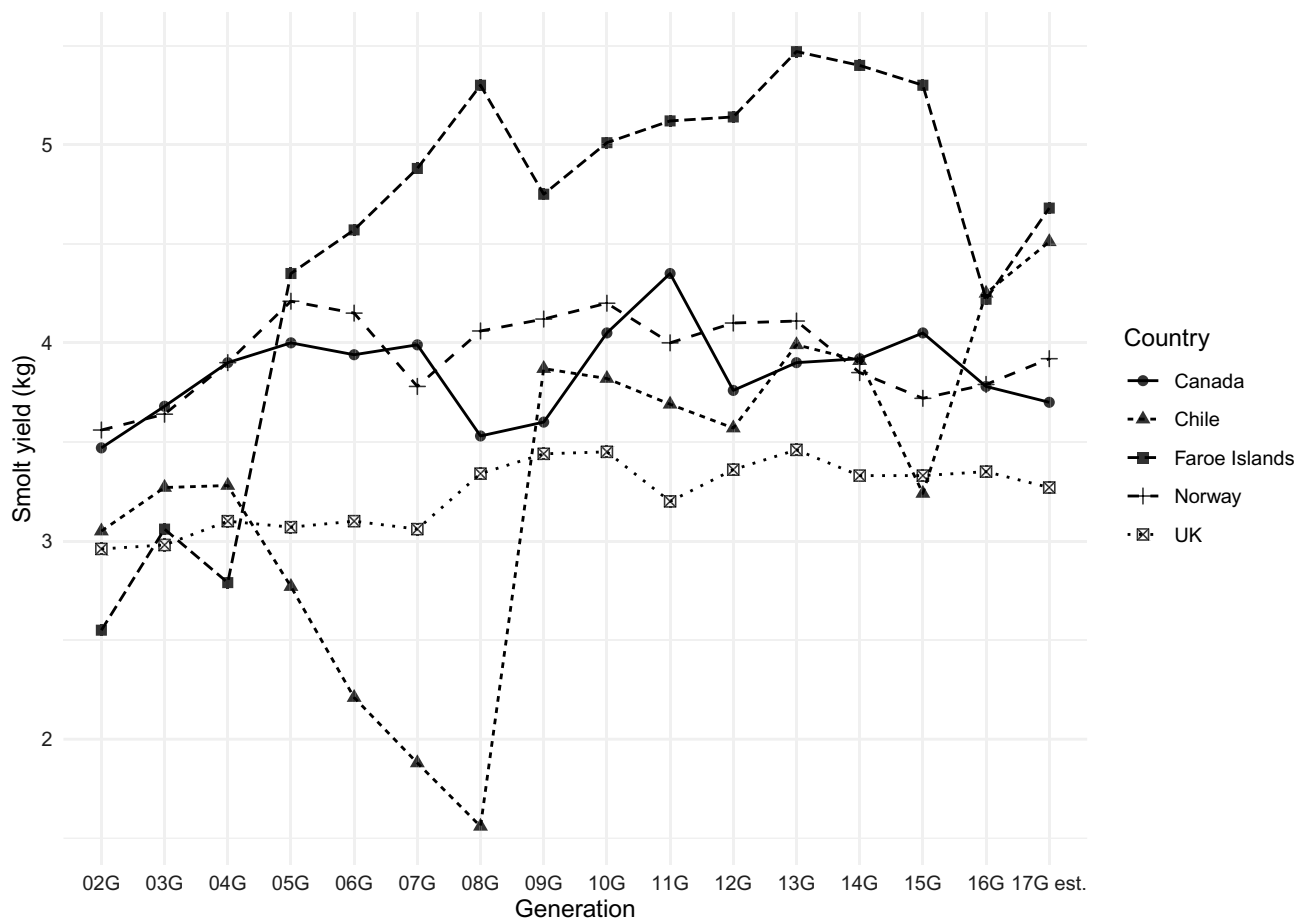


Fig. 5. Smolt yield (kg harvested gutted weight/smolt released) by country and generation (Source: Kontali Analyse AS).

closed transports of fish, treatment of bloodwater before release, monthly inspections of farms by food safety authorities and allowing growth being dependent of a satisfactory health situation. There are also smolt number restrictions that incentivize improvements in smolt quality, size and fish health aspects more strongly. Regulations can clearly have implications for production costs and vary between countries. A detailed review of these are outside the scope of the paper, but [Asche and Bjørndal, 2011](#) discuss regulations in all the countries and [Hersoug et al. \(2019\)](#) and [Chavez et al. \(2019\)](#) provides recent summaries for respectively Norway and Chile.

The production loss levels in Canada, Norway and the UK are relatively stable, with Norway's level clearly lower than the other two, and with some improvement in the UK in recent years. It is also interesting to note that the production loss level in Chile has reached a similar level as Norway after the disease crises.

Feed conversion ratio (FCR) usually is the single most important biological indicator for economic performance, as it together with feed price defines the feed cost per kilo. The economic feed conversion ratio (EFCR) describes the quantity of feed spent per kg of harvested fish. In [Fig. 7](#) the EFCRs for each country are presented. For the last generation (2017G, primarily harvested in 2018), we see that ranking in production cost corresponds quite well to EFCR. Scotland and Canada have the highest cost and the highest EFCR.

Norway experienced a steady EFCR for a long period, until increased mortality due to lice treatment started to kick in. Scotland has over a long period seen improvement, only to see EFCR return to higher levels again. We note though, that in later years Norway and Scotland have quite similar EFCR, even though costs are much lower in Norway. The cost advantage in feed thus stems from a lower feed price in

Norway, as well as larger scale of operations and higher productivity [Asche et al., 2018](#).

Over time, we recognize the influence of biological crises on this indicator as well. The sharp decrease in EFCR for the Faroe Islands, in the wake of their ISA-crisis, is related to poor performance during the crisis and their improved biological practice thereafter. As mentioned earlier, the build-up of biological issues in Chile was not only related to ISA and may be seen here as early as 2005. After the ISA-crisis, Chile stabilized at around the same level as Canada, before we observe a marked improvement in EFCR for Chile from 2015 to 2018. This is also reflected in costs, as Chile resumed position as cost leader in 2018.

5. Concluding remarks

It is well known that there is a global market for salmon ([Asche et al., 1999, 2018a](#)), where most consumers do not care where the salmon originates from and movements in prices are closely aligned over time.¹² Hence, the production cost is a key measure of each salmon producing country's competitiveness, although access to suitable production sites is vital for an industry's ability to respond to a good competitive position.

A unique data set allow us to show the development in the production cost at a triennial frequency in the five most important production countries for farmed Atlantic salmon for the period 2003 to 2018. The most striking insight is that except for the Faroe Islands, the

¹² There are some exceptions, although other product attributes appear to be more important than origin ([Uchida et al., 2014](#); [Roheim and Zhang, 2018](#))

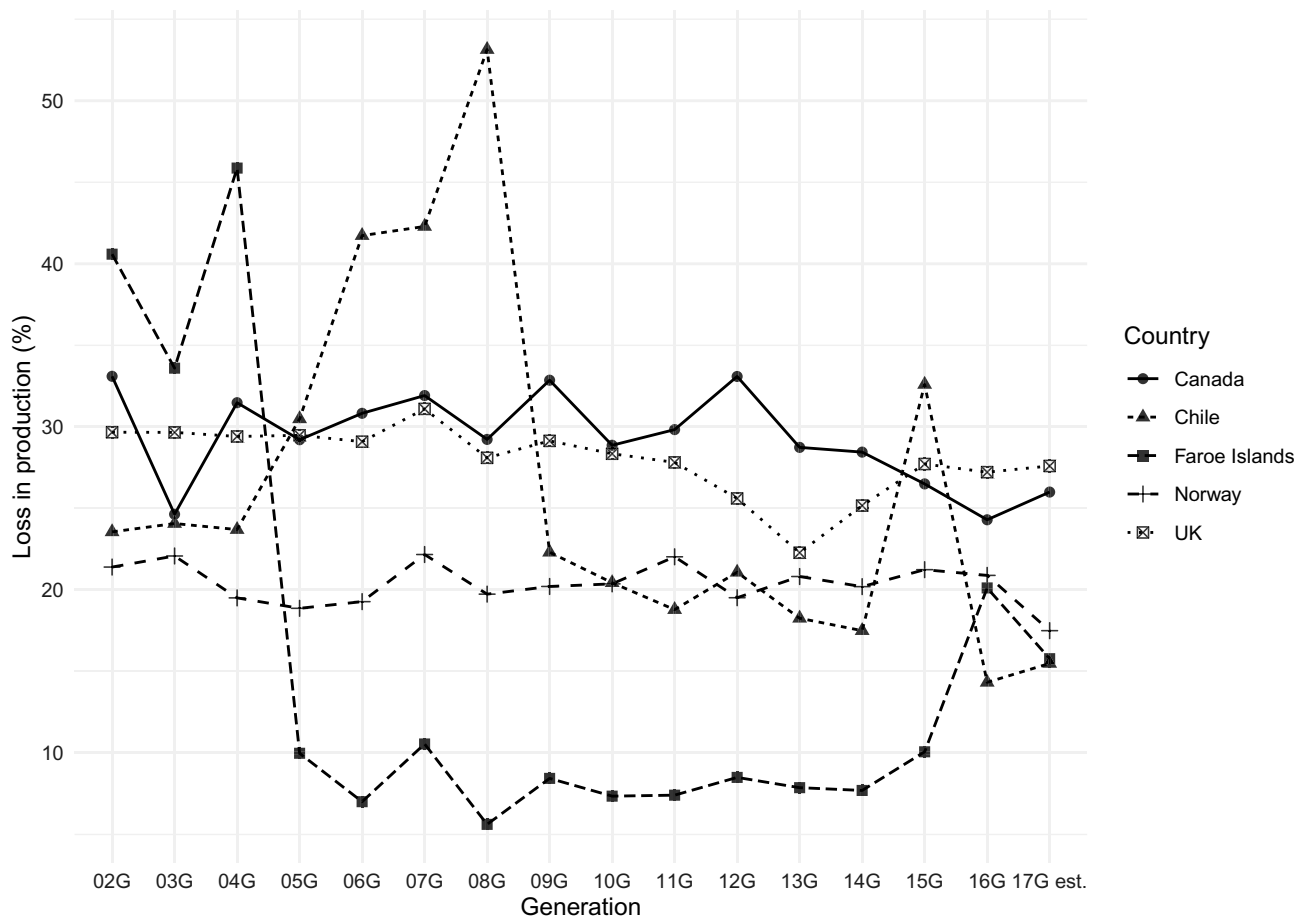


Fig. 6. Production losses measured as percentage of released individuals not harvested per country and generation (Source: Kontali Analyse AS).

real production cost over the whole period measured in USD has been increasing in all countries, moderately so in Canada and Norway and quite much so in Chile (even with the recent decrease). This is in stark contrast to the relatively long previous period of declining production costs and increasing productivity. Secondly, for those two countries with major disease outbreaks, the Faroe Islands and Chile, these disease outbreaks dwarf any underlying trend in production costs. Thirdly, the cost composition is relatively similar in all the countries, and the lowest cost producer at any time tends to do well in all categories rather than being particularly good in one dimension. This may not be too surprising given that biological challenges are the similar (although not identical), that the production technology is similar in all countries, that many of the larger firms have production in several countries and that suppliers are internationalizing, diffusing new innovations to all countries.

During the 2010s the Faroe Islands not only have the lowest production cost, but they are also clearly better performing than the other countries on other important indicators such as feed conversion ratio and production losses. These are strong indications of better

governance, and as the Faroe Islands is also the smallest of the five countries by quantity, it provides evidence that good governance may be more easily implemented with only three players. The latest development does not contradict this but shows that good governance does not take away the biological risk (in this case disease, lice and issues related to increased smolt size). The largest producer, Norway, has the lowest production cost in some years when its production share is increasing, but generally comes out as a good number two in most categories. It is also interesting to note how, except for when other countries are hit by a disease crisis, Canada and the UK are consistently scoring worst. It may then be no surprise that these two countries have been losing production share since the turn of the century.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

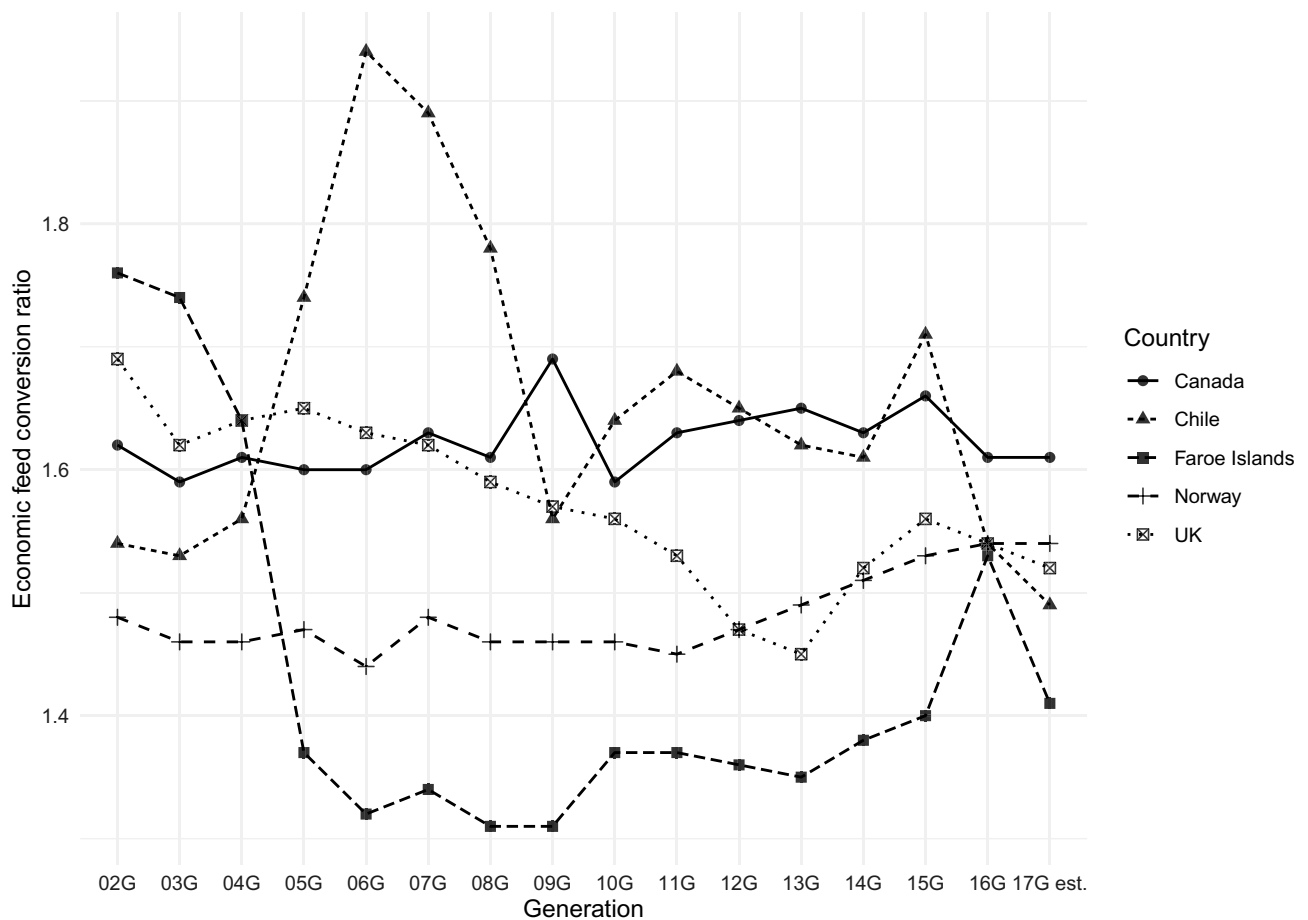


Fig. 7. Economic feed conversion ratio (kg feed/kg harvested gutted weight) per country and generation (Source: Kontali Analyse AS).

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Appendix A. Detailed cost data Norway, per kg HOG 2018-USD

	2003	2006	2009	2012	2015	2018
Smolt	0,41	0,33	0,40	0,43	0,40	0,52
Feed	2,00	1,97	2,11	2,37	2,17	2,20
Labour	0,27	0,25	0,27	0,32	0,34	0,42
Misc.	0,49	0,35	0,41	0,51	0,57	0,74
Depreciation	0,11	0,11	0,14	0,18	0,18	0,31
Harvest/packing	0,58	0,50	0,48	0,52	0,45	0,47
COP	3,85	3,51	3,83	4,33	4,11	4,65

Appendix B. Detailed cost data Scotland, per kg HOG 2018-USD

	2003	2006	2009	2012	2015	2018
Smolt	0,74	0,59	0,57	0,54	0,54	0,59
Feed	2,28	2,37	2,50	2,67	2,60	2,61
Labour	0,32	0,28	0,22	0,29	0,40	0,56
Misc.	0,53	0,43	0,41	0,58	0,72	1,20
Depreciation	0,15	0,15	0,18	0,17	0,20	0,29
Harvest/packing	0,60	0,53	0,38	0,49	0,63	0,67
COP	4,63	4,36	4,26	4,74	5,08	5,93

Appendix C. Detailed cost data Faroes, per kg HOG 2018-USD

	2003	2006	2009	2012	2015	2018
Smolt	0,58	0,53	0,44	0,38	0,37	0,62
Feed	2,63	2,10	2,06	2,17	2,04	2,24
Labour	0,23	0,35	0,23	0,23	0,26	0,33
Misc.	0,64	0,58	0,42	0,47	0,57	0,67
Depreciation	0,16	0,16	0,15	0,13	0,21	0,38
Harvest/packing	0,69	0,82	0,66	0,56	0,48	0,53
COP	4,93	4,54	3,96	3,94	3,92	4,77

Appendix D. Detailed cost data Chile, per kg HOG 2018-USD

	2003	2006	2009	2012	2015	2018
Smolt	0,30	0,37	0,91	0,61	0,61	0,53
Feed	1,52	2,22	2,57	2,49	2,64	2,19
Labour	0,09	0,14	0,33	0,24	0,28	0,20
Misc.	0,50	0,40	0,65	0,78	0,89	0,78
Depreciation	0,09	0,08	0,13	0,09	0,12	0,13
Harvest/packing	0,46	0,45	0,59	0,55	0,55	0,52
COP	2,96	3,66	5,17	4,75	5,10	4,35

Appendix E. Detailed cost data Canada, per kg HOG 2018-USD

	2003	2006	2009	2012	2015	2018
Smolt	0,52	0,45	0,46	0,41	0,41	0,53
Feed	2,31	2,19	2,39	2,87	2,29	2,33
Labour	0,38	0,37	0,36	0,40	0,33	0,51
Misc.	0,49	0,83	0,77	0,79	0,74	0,95
Depreciation	0,18	0,21	0,21	0,22	0,14	0,23
Harvest/packing	0,49	0,60	0,59	0,61	0,51	0,58
COP	4,37	4,65	4,79	5,30	4,43	5,14

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